the pier. This was laid in 1906, and it had become completely filled with sand and silt at the time of installing the register in 1908. This pipe should have been at least 8 inches in diameter, and there should have been another pipe outlet to the channel arranged so there would always be a slight movement of water thru the bottom of the well. Thus the inlets would tend to keep themselves clear. A 2-inch pipe is now in place several feet above the 4-inch pipe, and will, of course, do this to some extent when the water is above that point, but it is feared it will hardly prove sufficient for the purpose, and a special annual cleaning out of the bottom of the well and the lower inlet-pipe may be required.

The 10-inch float-guide pipe was installed in sections as the work of building up the pier progressed, but no special efforts were made to avoid the accidental deposit therein of wood, crusht stone, cement, and filth by careless workmen. Both well and pipe should be kept closed during the building operations of all bridge piers intended for the use of registering river gages. Where possible, more light and ventilation should also be provided for the vault room containing the registering apparatus.

The records thus far obtained at Hartford have been checked daily by eye observations of the ordinary river-gage, and have been found exceedingly accurate. They will doubtless prove of great value in the river work of this section.

THE METEOROLOGY OF MARS.

By Prof. SIMON NEWCOMB. [Reprinted from Harper's Weekly for 25th of July 1908.]

The study of the atmospheres of each of the other planets of our solar system is likely to add something to our knowledge of our own atmosphere, and we commend to our readers the following extract from a longer article by our distinguished colleague in astronomy.—*C. A.*

There are two points concerning Mars on which we can speak with a fair approach to certainty, and which will be most valuable in enabling us to interpret observations.

In the first place the atmosphere of Mars is so much rarer than that of the earth that the most delicate observations by Campbell with the great spectroscope of the Lick Observatory have failed to show any evidence whatever of its existence. This does not prove that no atmosphere exists, because there are other sources of evidence; but in the opinion of Campbell it shows that the density of the atmosphere can not amount to one quarter that of the earth. This view is strengthened by the comparative rarity of clouds upon the planet. Portions of the surface are seemingly obscured by vapors from time to time, but this is rather exceptional in any one region.

The other point on which we have some light, apart from the revelations of the spectroscope, is that of the probable prevailing temperature. A reliable estimate of this important element in Martian meteorology has been possible only in recent times, since the law of radiation of heat has been determined. The reasoning on which the estimate is based is so simple that I shall venture to set it forth.

We all know that a hot body is continually radiating heat, so that fire in the chimney place will warm the opposite walls of the room even if the air is below the freezing point. We feel this radiation only in case of very hot bodies, like the coals or flame of a fire. But accurate experiments show that every body, however cold it may be, radiates heat when left to itself without receiving heat from any outside source.[1] For example, during the night the earth radiates heat into space hour by hour, so that, as a general rule, its surface grows cooler during the entire night. Exceptions occur only when a current of warm air sets in. We know that, during the polar winter, although the Arctic regions receive a little warm air from the temperate zone, the temperature continually falls through radiation into the sky, month after month, until it reaches a degree far below any ordinarily experienced in our latitudes. It follows that any heat thus radiated by a planet, like the earth or Mars, must be gained from some source, else the temperature will fall below any that we ever experience on the earth, even below that of liquid air.

There is practically only one source from which the necessary heat is derived either for the earth or for a planet. That source is the sun. True, a little heat is received from the stars and a little from the interior of the earth, but these amounts are so small as to be scarcely measurable. Now, suppose a perfectly cold planet like the earth or Mars exposed to the sun's rays, and set rotating on its axis while revolving around the sun in a regular orbit. It will gradually absorb heat from the sun and so rise in temperature. As the temperature rises, heat will be radiated at a rate which continually increases with the temperature, as we see in the case of the fire. A point will finally be reached at which the amount of heat radiated is equal to the total amount received from the sun. Then the temperature will become stationary. It follows that if we know how warm a body must be in order to radiate a certain amount of heat, and if we know how much heat it receives from the sun, we can approximately determine its temperature.

The sun's radiation upon the earth has been determined with as much certainty as the case admits of by several modern physicists, high among whom stands our late Professor Langley, Secretary of the Smithsonian Institution. The result of these observations may be exprest in the following way. Imagine a flat vessel 1 inch thick, of any cross dimensions, filled with water and covered over water-tight. We thus have something which may be shaped like a very thin box. The main points are that the thickness of the vessel is exactly 1 inch, that it is filled with water, and that one surface is blackened so that it absorbs all the heat which falls upon it. Let this surface be exposed to the rays of the sun as shown in the figure.[2] It is found that the amount of heat falling upon it will suffice to raise the temperature of the water 1° C., that is, about 1.8° F., in a minute. This, then, is the measure of the heat which the sun radiates to a planet as distant as ours. Knowing it for the distance of the earth, we can easily compute it for Mars, because the intensity diminishes as the square of the distance increases. When Mars is nearest the sun each square mile of its surface receives about half as much heat as the earth, and at the greatest distance about one-third as much. This has long been known, but only recently has the other part of the problem been solved—that of determining how warm the earth or Mars must be in order to radiate all the heat it receives. The temperature that is necessary to produce this effect was long greatly underestimated. A curious instance is afforded by Langley's estimate of the temperature of the moon. He supposed that a body radiating as little heat as the moon does must be far below the freezing point. But when the law of radiation was finally established, it was found that Langley's observations showed the temperature of the moon to be not strikingly different from that which prevails on the earth, tho it might be much higher under a noonday sun and much lower when turned away from the sun. Very interesting is the agreement of the computed result with the temperature of the earth. It was formerly thought that the atmosphere served as a sort of blanket to the earth, which allowed the sun's heat to pass thru it and reach us, but permitted only of a very small amount being radiated back. Probably there is some such blanketing effect, but it is much less than was supposed. In fact, when we calculate about what temperature the earth ought to have in the general average, to radiate all the heat it receives from the sun we find it to be not very different from the actual temperature. The same remark applies to the moon. We thus have what every physical philosopher desires when he draws conclusions from a theory—practical test of the latter. The law of radiation, tho seemingly well proved by observation, might have been subject to more or less doubt as a method of determining the temperature of a planet had it not been confirmed by the case of the earth. Being confirmed, we apply it with confidence to estimate the temperature of Mars. A simple calculation leads to the conclusion that the temperature of the surface of that planet must be everywhere below the freezing point of water, unless in its torrid zone, under a high sun.

Another conclusion from the rarity of the air is that the vicissitudes of temperatnre are there far greater than upon the earth. We have remarked that during our night the earth cools off by radiating into space the heat which it received from the sun the day previous. We also know that the clearer and dryer the air the greater is the fall of temperature, while the presence of clouds lessens the fall by interfering with radiation. The radiation and absorption of heat by the atmosphere are much less than by the earth, so that during the night the air gives back to the earth an important part of the heat which it has received from it during the day. But on Mars the air is so rare that during the night it offers little impediment to the radiation, and does not contain much heat to return to the surface of the planet. Moreover, in our Arctic regions, during the long polar night, the fall of temperature is lessened thru the intercommunication of the air by winds between the Frigid Zone and the warmer regions where the sun is shining. Now on Mars this feature also is wanting, and there is no such powerful agent to limit the fall of temperature in regions where the sun is not shining.

We, therefore, conclude that during the night of Mars, even in the equatorial regions, the surface of the planet probably falls to a lower temperature than any we ever experienced on our globe. If any water exists it must not only be frozen, but the temperature of the ice must be far below the freezing point. When, as the Martian morning appears, the sun's rays shine upon this cold region they can not begin to melt the ice until the temperature of the latter rises above the freezing point. This will take a much longer time than it will on the earth, because the heat received is, on the average, less than half as great as what we receive. Without going into detailed calculations, we may say that it is scarcely possible that more than one or two inches of ice could be melted

[1] The law followed is that the higher the temperature of a body the more rapidly it loses heat by radiation.

[2] Not reproduced here.

during a Martian day. Thus, while it is possible that under a noonday sun the temperature of the air and, perhaps, of the solid rock may rise above the freezing point of water, all the heat received must be completely lost when the sun sinks in the west. The most careful calculation shows that if there are any considerable bodies of water on our neighboring planet they exist in the form of ice, and can never be liquid to a depth of more than 1 or 2 inches, and that only within the torrid zone and during a few hours each day. We may claim with certainty that in the polar regions of Mars the temperature can never rise to anything near the freezing point of water.

Here a difficulty may at once occur to the critical reader. Are not the snow caps of Mars actually seen to melt away under the influence of the sun's rays? I reply in the negative. There is no evidence that snow like ours ever forms around the poles of Mars. It does not seem possible that any considerable fall of such snow could ever take place, nor is there any necessity of supposing actual snow or ice to account for the white caps. At a temperature vastly below any ever felt in Siberia, the smallest particles of moisture will be condensed into what we call hoarfrost, and will glisten with as much whiteness as actual snow. This is a familiar fact which requires no elucidation. We should expect hoarfrost to form around the poles of Mars if there is the slightest tinge of vapor in its thin invisible atmosphere. We do actually see this white formation.

But why does this hoarfrost disappear under the sun's rays if the temperature remains below the freezing-point? The reply is that, as physicists and meteorologists well know, snow and ice slowly evaporate even at the lowest temperature that can be produced. The rate of evaporation is so slow as to be unnoticed, except when very exact observations are made. We should, therefore, expect that in the absence of a perceptible atmosphere, when this thin coating of frost crystals, perhaps a millimeter in thickness, is exposed to the sun, it will gradually evaporate day after day, leaving the darker surface under it exposed. This is precisely what we see to take place. Thus, so far as the ordinary facts are concerned, there is nothing to surprise us in what we see going on upon Mars at so low a temperature. The higher elevations in the temperate and torrid zones of the planet would naturally now and then be covered by frost during the night, which might continue during the following day, or for a number of days. Thus we have a kind of Martian meteorological changes, very slight indeed and seemingly very different from those of our earth, but yet following similar lines on their small scale. For snowfall substitute frostfall; instead of feet or inches say fractions of a millimeter, and instead of storms or wind substitute little motions of an air thinner than that on the top of the Himalayas, and we shall have a general description of Martian meteorology.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Librarian.

The following have been selected from among the titles of books recently received, as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies. Most of them can be lent for a limited time to officials and employees who make application for them. Anonymous publications are indicated by a ——.

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